RESOLVING LR TYPE CONFLICTS AT TRANSLATION OR COMPILE TIME

ABSTRACT.
The paper considers circumstances in which it is advantageous to resolve reduce-reduce conflicts at compile time, rather than at compiler-construction time. The application considered is that of translating English to one of the Romance languages, such as Italian where adjectives and nouns have distinctive forms depending on their gender.

As an example of the application area of the algorithm that this paper describes, consider the problem of natural language translation with respect to a restricted set of sentences, such as may occur in e.g. translation systems for tourists, voice-recognition systems, air-traffic control, dispatchers for trucks and taxis, police radio transmission, sport coaching, text messaging, lab results, and various medical and military contexts. Normal LR parser construction using attribute grammars are some of the tools employed for translation systems, but there are quite simple cases where constructing the complete parser in advance is not feasible. For the purposes of illustration, let us initially consider the problem of translating from English to Italian a trivially small set of sentences of the form:

The <adjective> student is a <adjective> <person>.

e.g. The Italian student is a tall man (Lo studente Italiano é un uomo alto)

or The Italian student is a tall woman (La studentesse Italian é una donna alta)

All the translation engines available on the web that we have tried, including those provided by Google, Yahoo, etc, translate “The Italian student is a tall woman” partially or wholly in the masculine form (but will usually correctly translate “The tall woman is an Italian student”).

Restricting, for the sake of exposition, the set associated with the <adjective> qualifying “student” to {Italian, Austrian}, and set associated with the <adjective> qualifying “person” to {tall, good}, and that associated with <person> to {man, woman}, a possible grammar[1] for such sentences, in which gender is specified using the prefixes “m_” and “f_” for the purpose of facilitating translation into Italian, is:

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sentence → m_the  m_adjective-student  IS  m_a  m_adjective-person
         |  f_the  f_adjective-student  IS  f_a  f_adjective-person

m_the → the                                                  printf("Lo")
f_the  → the                                                 printf("La")
m_the-adjective-student → m_adjective_1  m_student           printf(SavedAdjective)
f_the-adjective-student → f_adjective_1  f_student           printf("SavedAdjective)
m_adjective_1 → Italian                                      SavedAdjective = "italiano "
              | Austrian                                     SavedAdjective = "austriaco"
f_adjective_1 → Italian                                      SavedAdjective = "italiana "
              | Austrian                                     SavedAdjective = "austriaca "
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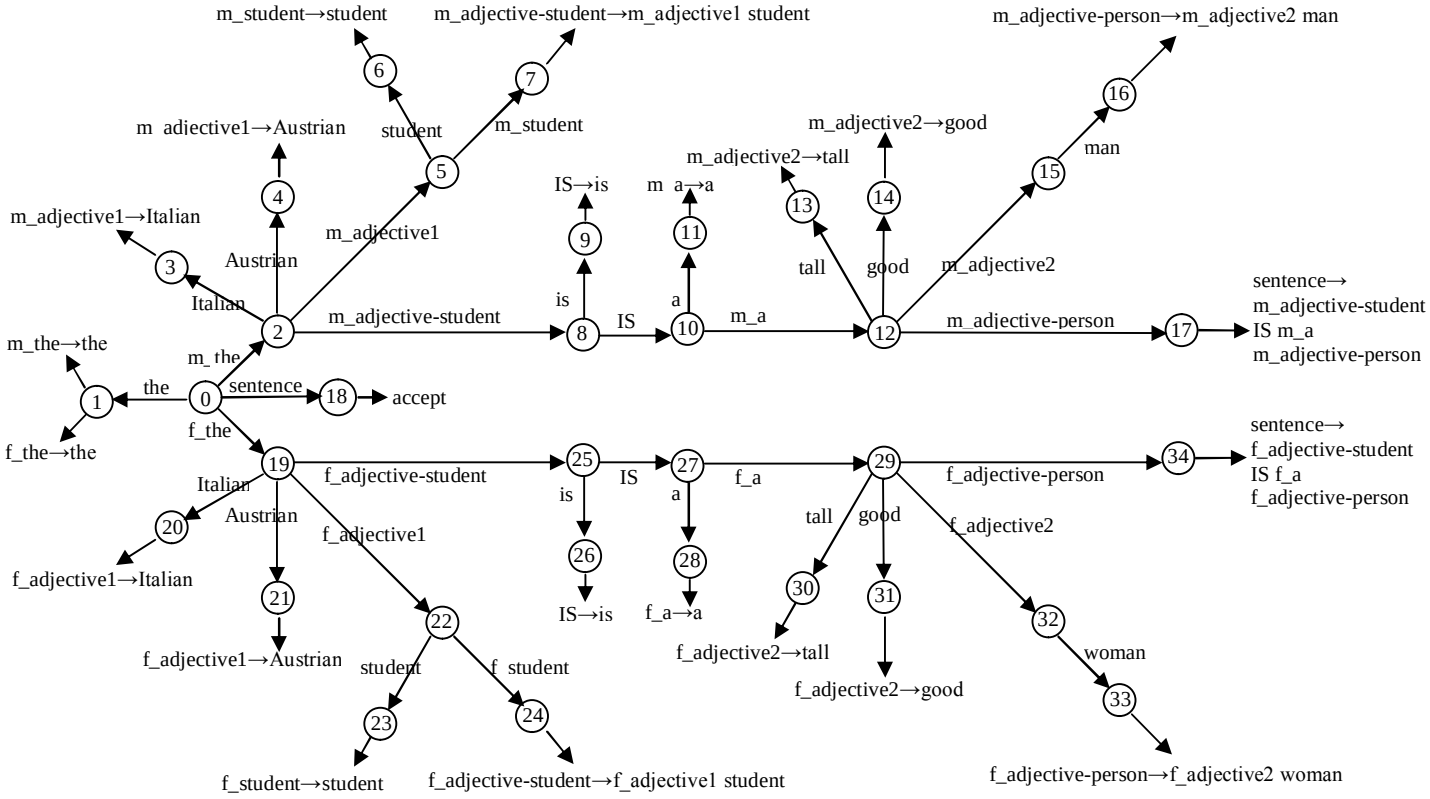
[1] with some code-generation (in pseudo-C) shown in the manner employed by YACC. SavedAdjective is a string variable

m_student → student	printf(“studente ”)
f_student → student	printf(“studentessa ”)
IS → is	printf(“é ”)
m_a → a	printf(“un ”)
f_a → a	printf(“una ”)
m_adjective-person → m_adjective_1 man	printf(“uomo” SavedAdjective)
f_adjective-person → f_adjective_1 woman	printf(“donna” SavedAdjective)
m_adjective_2 → tall	SavedAdjective = “alto”
| good	SavedAdjective = “bueno”
f_adjective_2 → tall	SavedAdjective = “alta”
| good	SavedAdjective = “buena”

The parser for this grammar is supplied in the following parsing machine:



The above machine contains a reduce-reduce conflict at state 1.
The grammar is a LR(6) one, and the contexts for m_the→the are:

Italian student is a tall man
Italian student is a good man
Austrian student is a tall man
Austrian student is a good man

while the contexts for f_the→the are similar except for the replacement of “man” by “woman”.

Note 1. Simple extensions to the above grammar provide sentences such as

the student is a man who is tall

in which “man” in this case is not the last word.

Note 2. For the purposes of the translation program, the English sentence provided is assumed to be a valid member of some set S of sentences. The translation program is not required to check that this is so. Hence the grammar employed may be one for a superset of S, and include sentences which are not in S and are not expected to ever occur in practice, such as:

the tall student is a short man

Note 3. The set S of sentences may include ones such as

the tall student is a happy person

in which the gender cannot be determined (and so the gender the translation makes use of in these circumstances is arbitrary).

Note 4. The gender involved can be determined in some cases by the adjective employed. For instance the gender involved may be taken to be male in:

the student is a brawny person

or: the student is macho

while the female gender is implied by sentences such as:

the student is a buxom person

or: the student is pretty

There are several thousand English adjectives. If we alter the above grammar to provide for a selected thousand of them, then since adjectives occur at two places within the the set of sentences, there will be a million contexts of length 6 for both m_the→the and f_the→the in the resulting parsing machine. In addition there are thousands of occupations besides “student”. It should be clear from the above illustrative example, fairly simple subsets of English may be considered in which the number of contexts needed to resolve reduce-reduce conflicts is immense, even immense enough to exceed the storage capacity of present-day computers. Such a large number of contexts will also be obtained where the number of choices at each point in the set of sentences is small, but the number of places where there are choices is large. In the above cases, the number of contexts rises exponentially with the product of the sizes of the sets of choices involved, but the number of additional states that are generated rises only with the sum of these sizes.

Furthermore if we allow strings of adjectives, such as:

the student is a tall, thin, debonair man

and do not place an upper bound on the size of such strings, then the number of possible contexts required to resolve reduce-reduce conflicts in the resulting parsing machine becomes unbounded (and associated grammars may not be LR(k) for any k).

Without evaluating the contexts at state 1 at compiler-construction time (impractical in the case where a much greater number of adjectives and occupations is provided for than that in the above grammar), we can nevertheless employ the above machine to resolve the reduce-reduce conflict in the cases described above by considering the actual context obtained at translation time. Consider, for example, the sentence

The Austrian student is a tall woman

In the case where “m_the→the” is chosen at state 1, the parse of the sentence, using the parsing machine would lead to state 2, and then (with next input symbol “Italian”) to state 3,

where the production “m_adjective1→Italian” would be carried out. This would lead to state 5, and then (with next input symbol “student”) to state 6 and production “m_student→student”. This would lead to state 7 and the production ”m_adjective-student→m_adjective1 student”, leading to state 8, and then (with next input symbol “is” to state 9 and production “IS→is”, leading in turn to state 27, and then (with next input symbol “a”) to state 11. The production “m_a→a” follow, leading to state 12 and then (with next input symbol “tall”) to state 13. Here the production “m_adjective2→tall” would be carried out, leading to state 15. At this stage the next input symbol would be “woman”. But no action for “woman” is defined at state 15, showing that “Italian student is a tall woman” is not a valid context of length 6 of “m_the→the” at state 1. On the other hand, by a similar procedure to that described above, we can show that, if “f_the→the” is chosen at state 1, then the context “Italian student is a tall woman” will lead to state 33, showing that that context is a valid context of length 6 for “f_the→the” at state 1. This resolves the conflict at state 1. The above method of resolving this conflict, will remain unchanged, even if the grammar is augmented to (say) allow a thousand adjectives instead of only “Italian” and “Austrian”, and a thousand adjectives instead of only “tall” and “good”.

This is an example of the cases described above where the number of contexts required to resolve a reduce-reduce conflict at translation-construction time is an exponential function of the sizes of the set of choices involved, but the number of parsing machine states required is a function only of the sum of these sizes, and further the number of steps required to resolve the conflict at translation time is a function only of the number of such sets of choices.